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The Role of Renewable Energy in Advancing SDG 7: Ensuring Clean and Affordable Energy

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Abstract

The key challenge of the modern world is sustainable energy development, which matches traditional energy sources, leading to severe environmental and economic problems. Renewable energy sources (RES) are essential to reducing CO_2 emissions and increasing energy efficiency towards achieving SDG 7. The study aims to explore the impact of RES on affordable and clean energy, the development trends, and the main barriers to implementation. The method is based on statistical analysis, comparison, the content of scientific sources, and case studies of countries' political strategies. The results confirm that an increase in the share of RES in the global energy balance contributes to reducing dependence on fossil fuels, improving the environmental situation, and economic development. Several areas remain as main barriers, namely the high costs of RES initial investments, lack of infrastructure, and RES integration and regulatory restrictions. It was concluded that compelling government support and favourable political conditions tend to be associated with higher rates of RES implementation. In the study, one of the most practical values is determining the directions of political and economic support for RES to accelerate the energy transformation and the environmental load. The results obtained can also be used in developing state programmes to support RES and implement effective models for their integration into national energy systems.

Keywords

Renewable energy sources; Sustainable development; SDG 7; Energy efficiency; Decarbonisation

Introduction

Energy security and environmental sustainability are the best issues in the world. Countries are facing the depletion of fossil fuel reserves, increasing energy prices, and the adverse impact on the environment from fossil fuels, and they have no choice but to find a way out of this situation. However, renewable energy sources (RES) are increasingly important in helping to reduce dependence on traditional energy sources through emissions of greenhouse gas (Gayen, Chatterjee and Roy, 2024; Kandpal *et al.,* 2024). Within the framework of Sustainable Development Goal 7 (SDG 7), special attention should be paid to the availability and efficiency of clean energy, which is paid special attention to by modern energy policies (Küfeoğlu, 2022).

Goal 7: Affordable and Clean Energy aims to ensure access to affordable, reliable, sustainable, and modern energy for all by 2030. It includes several key targets established by the United Nations to guide the global energy transition. These targets are as follows:

1. Ensure universal access to affordable, reliable, and modern energy services by 2030;
2. Substantially increase the share of renewable energy in the global energy mix by 2030;
3. Double the global rate of improvement in energy efficiency by 2030;
4. Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced, cleaner fossil-fuel technologies;
5. Expand infrastructure and upgrade technology for supplying modern and sustainable energy services, particularly in developing countries and small island developing states.

These targets serve as a roadmap for policymakers and energy stakeholders to align national strategies with global sustainability priorities and measure progress accordingly.

With limited access to centralized energy sources, small generation systems (solar panels, wind turbines, autonomous mini-power plants, etc.) are becoming increasingly important. They require self-synchronization mechanisms to ensure frequency stability even in the absence of a main frequency source. The problem is particularly relevant in the context of military conflicts and risks, given the new types of weapons targeting energy infrastructure (The Kyiv Independent, 2025). Given this, priority is given to ensuring independent frequency synchronization for inverters that generate electricity, which will make it possible to create autonomous areas synchronized with the general power grid.

At the same time, as practice shows, the issue of synchronization for small power generation sources is also important for stable European countries. In particular, in April 2025, Spain experienced a massive power outage due to a miscalculation by the REE operator. A government investigation showed that the company had underestimated demand during peak hours. The frequency of European power grids must remain at 50 Hz, and minor deviations, particularly due to overload, can have serious consequences.

We can see now that RES is a very good thing for the economy and the environment since recent scientific studies demonstrate precisely this. Specifically, as mentioned by Azizi *et al.* (2025), Xia, Liu and Yang (2023), Duggan (2025), and Ramasubramanian and Ramakrishna (2023), RES play an essential role in the decrease in CO_2 emissions. Various studies prove the resistance to the implementation of RES is characterized by the high initial investment cost (Wu *et al*., 2024), the need for the modernization of the energy infrastructure (Novikau, 2024), and regulatory barriers (Coscieme *et al*., 2023).

Much research has been conducted, yet there are gaps in understanding the optimal mechanism for combining RES in national energy systems, the effectiveness of policy efforts to support green energy, and the trust that digital technologies make in RES development. Other questions that are still open include the balance between renewable and conventional energy sources in an environment with present economic constraints. The relevance of creating national synchronization standards for small power generation sources is obvious, as this will minimize risks in the field of energy supply. Essentially, the process should be understood as the coordination of the parameters (voltage, frequency, phase) of these sources with the parameters of the main electrical network or other power source to ensure their compatible operation without disruptions. This allows energy from different sources to be combined, increasing the reliability and efficiency of the power supply system, especially in distributed generation.

This study aims to review ways to integrate the development of RES to contribute towards the achievement of Goal 7 of the SDG for a detailed analysis of clean energy development trends in the current scene and significant impediments to the implementation of RES. The purposes of this study consist of: 1) analysing the economic, social, and environmental benefits of RES. 2) Evaluating the feasibility of policy strategies applied to promote green energy. 3) revealing the significant barriers and constraints for the project RES. 4) Formulating recommendations for the future of renewable energy in the sustainable development framework

Literature Review

The research on renewable energy sources, within the context of Sustainable Development Goal 7 (SDG7), has been extensively broadened with regard to policy, technological development, and environmental and economic impacts. The contribution of RES to CO_2 reduction and energy efficiency has been given good attention (Azizi *et al*., 2025; Hilili, Akadiri and Eneanya, 2024; Xia, Liu and Yang, 2023). Finally, political strategy is also considered for green energy development (Coscieme *et al*., 2023; Duggan, 2025; Zhou *et al*., 2023). A study of the impact of energy strategies on sustainable development in other countries in the regional context is undertaken, such as Ghana (Ametepey *et al.,* 2024), Algeria (Chabouni *et al*., 2024), Nigeria (Hilili, Akadiri and Eneanya, 2024), India (Shivanna and Rangappa, 2024), and EU countries (Osuma and Yusuf, 2025).

That is why it is necessary to analyse the educational issues of training specialising in renewable energy (Batsurovska, 2023; Havrysh *et al*., 2020). Active research is also going on innovative approaches to integrating RES into urban environments and infrastructure, such as that conducted by Sanusi (2024) and Skaloumpakas *et al*. (2024).

Other papers focus on the relationship between the financial and institutional arrangements for deploying RES (Wu *et al*., 2024; Xia, Liu and Yang, 2023). Some concentrate on the economic and social aspects, such as the effects of digital technology and R&D on energy transition (Pata, Karlilar and Kartal, 2024; Ramasubramanian and Ramakrishna, 2023). Lastly, further research is conducted using a detailed study of the interaction between different sectors of the economy and RES. For instance, Novikau (2024) points out that energy research should have been the main direction in attaining sustainable development. Solanki and Birman (2025) emphasized nature-based approaches to RES. Zhang *et al*. (2023), in turn, analyze how globalization, demography, and democratic processes contribute to RES development in South Asia simultaneously.

The literature reviewed indicates that there has been an increased academic involvement in analysis of how to implement the concepts of environmental sustainability in a model of economic and social development and especially green economy, circular practices, utilization of renewable energy sources, conservation of biodiversity and safeguarding cultural landscapes. Ostapenko *et al.* (2024) systematize the global coverage of stimulating green economy during the period of financial crisis and prove that selected types of policies and international collaboration can help to reduce the severity of the economic crisis and advance the environmental agenda. Liubchych *et al.* (2023) concentrate on the Ukrainian experience and examine the subject of environmental interests of the masses, disclosing the importance of such civic stimulations and institutional openness as the promotion of ecological agendas. Antonescu (2023) presents a rich and in-depth case study of mountain bio-diversity in Romania by highlighting the importance of conservation to ecosystem services and regional socio-economic balance. Mulugeta and Leta (2021) analyze how sustainable energy transition differs, at a household level, to determine social-economic, cultural, and infrastructural factors that influence domestic investor attitudes toward renewable energy adoption at an individual household scale. Zavadskykh *et al.* (2025) evaluate the opportunities of circular economy principles in the Ukrainian enterprises stressing the importance of innovation, minimization of waste, and resource efficiency as strategic competitiveness instruments. In addition to these views, Li *et al.* (2025) discuss the sustainability of cultural landscape preservation and change to accommodate sustainable tourism, pointing out the interrelated nature of heritage protection, community involvement and the resilience of an entire ecosystem. Collectively, these works can portray a multidimensional perception of environmental sustainability being incorporated into the economic and social framework, which can be helpful in policymaking and community-driven projects.

They also highlight current trends in energy efficiency and renewable energy development. Sotnyk *et al.* (2023) conducted a bibliometric analysis of research in household energy efficiency, which allows the assessment of scientific progress and the main directions of industry development. Kovalko, Eutukhova and Novoseltsev (2022) consider the ecological transformation of energy services as a business model that facilitates the transition to a low-carbon economy. Hrinchenko *et al*. (2024) focus on energy security management using an assessment of the technical condition of enterprise equipment. All three studies emphasize the importance of efficient energy management and its role in ensuring sustainable development.

A key issue is the coherence between the RES policy and the actual mechanisms for its implementation. Pata, Karlilar and Kartal (2024) examine the role of digital technologies and research investments in transforming the German energy sector. Similarly, Ramasubramanian and Ramakrishna (2023) investigate the correlation between SDG7 and other sustainable development goals and the importance of considering trade-offs and synergies. The impact of trade and market openness in the studies is also studied on the implementation of RES (Zhou *et al.,* 2024). Suraj *et al*. (2024) analyze the socio-economic aspects of the energy supply and their role in sustainable energy development using corporate initiatives. Moreover, Vivek *et al.* (2023) identify the possibility of bioenergy aimed at the sustainable development of India.

They have made impressive headway with research, but it has not yet resolved the balance between renewables and traditional energy that should be struck, particularly in developing countries. Moreover, proper financial support and a lack of unified international regulatory standards are deficient, slowing down the transition of clean energy to a global scale.

Methods

In this research, both quantitative and qualitative research designs were used as a mixed-methods design since this approach would guarantee the validity and depth of the research findings. In order to implement this mixed-methodology in practice, we started with the quantitative data gathering on the deployment of renewable energy, CO_2 emissions reduction, and energy efficiency measures referring to the period 2010-2025. The major data used were the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), World Bank, Eurostat, and national energy agencies. We extracted statistical tables of the latest datasets manually, put them in a spreadsheet, and cleaned them (related to the consistency of the units, e.g., megatons of CO_2 percent efficiency) and adjusted indicators to correspond to the same frequency (annual). Then, two visual models were created: a trend analysis on contributions to the reduction of CO_2 emissions of a given type of RES. The first one is energy efficiency in the industry and transport sectors. Line and bar graphs were created in Microsoft Excel to build these models. The values were ascertained on processed tables (Tables 1 and 2) and verified across-folded in secondary reports where there were errors in data provision.

These models were built using the line and bar graphs through Microsoft Excel. The values were determined on processed tables (Table 1 and Table 2) and across-folded in secondary reports in case of errors in the provision of data. In order to assure accuracy and reproducibility of the data represented in figure 1, table 1 below shows the actual figures that will be used in drawing the graph depicting the process of reducing the CO_2 emissions level using various sources of renewable energy (RES) between 2010 and 2025. Values used were retrieved in international energy reports and peer reviewed literature as sources used in the manuscript. To measure this relative effect of the various types of RES we computed the annual growth rates and the absolute deltas on the time series.

We quantified this relative effect of the different types of RES by computing the annual growth rates and the absolute deltas on the time series. To be able to compare the scenarios, the values that were projected to be reached by 2025 were estimated by the

linear approximation using the growth rate over the period of 2010 to 2020. On the qualitative side, we performed content analysis on 42 documents: 28 peer-reviewed articles and 14 strategic policy documents (UN SDG reports, IRENA, IEA, and national energy ministries). All documents were read to retrieve the mention of the barriers of RES, support mechanisms, and integration techniques. Separately, we coded such emergent themes as financial barriers, grid integration, policy instruments, and decentralized systems using MAXQDA software. When the frequencies and co-occurrence of such codes were determined, they were clustered and prioritized.

In order to compare political strategies of the countries (Germany, China, India, Nigeria, and Ukraine), we developed the cross-case matrix. In every nation, we enumerated the primary legislative measures, financial tools (e.g., subsidies, tax credits), technological measures, and institutional frameworks. This was summarized in a comparative table of common trends, as well as different approaches. Last but not least, we simulated the potential integration of smart grid elements through practical pilot implementations of energy authorities as an example. We have studied architectures of intelligent switching systems and formed a hypothetical implementation process (sensors implementation up to grid isolation algorithms) concerning the rural areas of Ukraine.

The quantitative part focused on using simple statistics to assess how often renewable energy sources (RES) are used and how much they help reduce CO_2 emissions. The main data came from international organizations like the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), and the World Bank, as well as various national statistical offices. The qualitative component involved content analysis of scientific literature, policy sources, as well as the strategic frameworks at the country level to determine the barriers, drivers, and institutional processes concerning the RES development. The analysis of the effectiveness of renewable energy policies used a method of comparative case studies, analyzing the policies of some selected countries in regard to different economic and geographic conditions (e.g., Germany, India, Nigeria, China, and Ukraine).

Additionally, the methods of modelling were used to calculate potential scenarios of the development of the RES depending on policy and investment options. This enabled the determination of the ability to implement proposed strategies in line with SDG 7 targets. The interaction of smart grids and decentralized energy systems was studied on the basis of the recent data on intelligent switching systems and energy efficiency indicators, through scenario analysis. The determination of methods has been informed by the sophisticated and cross-sectoral aim of the research question, including technology, economy, and policy aspects. The instrument used to make conclusions involved triangulation of data sources and the reliability and robustness of conclusions.

Results

Renewable energy is key to achieving Sustainable Development Goal 7 (SDG7), which aims to provide affordable, reliable, sustainable, and modern energy. Even though the three significant sources of energy on the earth – coal, oil, and natural gas – still make up most of the energy blend worldwide, their direct impact on the environment is hostile. Renewable energy sources such as solar, wind, hydro, and bioenergy can play

environmentally friendly and economically viable roles. Part of RES is that they help to reduce greenhouse gas emissions. Reducing carbon emissions from renewables is essential to slow climate change (Wernersson *et al*., 2024). The transition to RES can significantly reduce the dependence on fossil fuels, thus improving air quality and decreasing morbidity associated with environmental pollution.

Renewables also play a significant role in the other key aspect of SDG 7, energy accessibility. Although centralized energy supply is underdeveloped or inaccessible in many regions, particularly in developing countries. A possible vehicle for solar panels or wind turbines to give remote and isolated communities with no access to modern energy services (Khaleel *et al.,* 2023) is decentralized renewable energy solutions. In addition, renewables help to create jobs and grow the economy. Investment and employment are fostered as this renewable energy sector rapidly develops innovative technologies. The renewable energy industry has already helped millions get jobs worldwide, and this will continue to be the case, says the International Renewable Energy Agency (IRENA, 2023).

Although the apparent advantages of renewables exist, they are marred by some challenges in introducing them. Notably, the need for significant head start investment, infrastructure development for RES integration into energy systems, and political and regulatory instability in certain countries may delay the transition to clean energy. However, at the same time, digital technologies in business life are actively introduced, energy networks are developing, and international organizations' support contributes to overcoming the identified barriers. Therefore, renewables play an important role as a mitigating factor for achieving SDG 7 as they ensure environmental sustainability, promote economic development, and enable universal energy worldwide. However, the successful implementation of this goal requires innovative technology and works with policies and international cooperation.

Global efforts are on the verge of eliminating our dependence on fossil fuels, quickly switching to renewable energy sources (RES), and creating sustainable energy for the world. Investment in solar, wind, hydro, and bioenergy production is helping to reduce dependence on fossil fuels. Many governments are adopting the introduction of financial mechanisms and subsidies by many governments to stimulate the development of renewable energy. Developing countries are currently in the process of implementing renewable energy in order to strengthen energy security in a regional context. Dynamics are still positive even though challenges remain with financing, infrastructure, and technology development.

A separate problem is potential frequency fluctuations due to network overload. Today, it is necessary to develop a special frequency synchronization standard that will allow maintaining the set base frequency even without main power plants, to prevent the problem of rolling blackouts without the possibility of forming autonomous areas. Correcting the situation at the standard level will ensure the accuracy and reliability of the system, uninterrupted operation of systems even in the presence of disturbances, as well as flexibility in terms of adaptation to different requirements and conditions, and interoperability (different systems can interact effectively with each other using a single

synchronization standard). Table 1 summarises the main trends in developing renewable energy sources on a global and regional scale.

Table 1: Main trends in the development of RES in the global and regional context

Trend	*Global context*	*Developing countries*
Increase the share of renewable energy in the energy balance	In 2023, more than 30% of global electricity generation came from renewables.	Countries in Africa and South Asia are expanding solar and wind energy use.
Reducing the cost of renewable energy	The cost of solar and wind power has fallen by more than 80% over the past two decades.	The low cost makes renewables attractive for energy supply in low-income regions.
Development of battery technologies	Investments in energy storage systems are increasing to improve the stability of energy systems.	Some countries have started using batteries for decentralised power grids.
Political support and subsidies	The US, EU, and China actively subsidise renewable energy, contributing to the sector's growth.	Latin American and Asian countries are gradually introducing support for renewable energy through government programmes.
Decentralisation of energy supply	The share of microgrids and autonomous power systems based on renewable energy is increasing.	Solar home systems and mini-hydroelectric power plants are prevalent in rural areas of Africa and Asia.
Development of green hydrogen energy	Hydrogen is becoming an important component of future energy, especially in Europe and Japan.	Countries in the Gulf and Latin America are beginning to develop hydrogen infrastructure.
Challenges in financing	High initial investment and the need for innovation in the energy network sector	Limited access to capital makes it difficult to scale renewables in developing countries.

Technological advances, political support, and the dropping cost have driven global trends to show a rapid increase in the use of renewable energy sources. Renewables are a key tool to close the energy access gap and fight poverty in developing countries. However, financing and infrastructure challenges still need to be overcome to achieve sustainable development in the sector.

Intelligent switching systems are positioned as effective modern solutions for managing and optimizing the switching (connection) of various devices or networks, managing power distribution, optimizing load, and improving power supply reliability. Smart switching systems can analyze traffic and network performance data to ensure optimal data routing and minimize delays; they can automatically adjust and reconfigure the network based on needs and conditions; they use analytics to detect anomalies and problems in the network, block threats, and predict future needs. Unlike traditional systems, where energy is transmitted in only one direction, a smart power grid provides

two-way communication and control at all levels, from the electricity producer to the end consumer (The Kyiv Independent, 2025). Smart switching is currently being implemented in the high-voltage context, but it seems necessary to extend it to the low-voltage side and to the consumer side, using the same protocols. The integration of smart switching systems requires the introduction of standards for such devices and their implementation in local networks. In addition, it is necessary to include in the national standard a requirement for the use of smart switches that automatically isolate damaged sections of power lines, especially in rural and mountainous areas, which will improve network efficiency and ensure flexible load distribution management in the event of accidents (Energy all, 2025).

The development of special-purpose transformers is a topical area in the development of smart switching systems. In particular, an innovative patented solution was the testing of a lambda transformer (commercial name of the device "SFTSZ"), which is capable of reproducing one of the phases or zero when it is broken, as well as making instant "seamless" switching between two three-phase lines (Energy all, 2025). During practical testing of the device, an additional need arose for the installation of special meters, monitoring of breaks, and the use of special contactors that could disconnect the network at the right place. This is because in the event of a load imbalance, the transformer generates energy flows from the unloaded phases to the loaded ones, which is not taken into account by standard meters. Smart Grid is currently positioned as a relevant concept for electrical networks, actively involving information and communication technologies for more efficient power management. It uses digital technologies to collect and exchange data, allowing for more flexible and efficient management of the power system, rapid response to accidents, reduced production costs, and increased consumer engagement. Smart Grid involves the use of smart meters, automated load management by automatically switching consumers to more favorable tariffs or reducing load during peak hours, as well as the development of energy storage systems and reducing environmental impact.

A comprehensive approach for analyzing RES impact on CO_2 emissions reduction (Figure 1) and improvement of energy efficiency (Figure 2) was used based on official sources of data, such as reports by the International Energy Agency (IEA, 2023), the International Renewable Energy Agency (IRENA, 2023), the World Bank, other academic institutions. The processed statistical data concerning the dynamics of CO_2 radiation reduction using different types of RES (solar, wind, bioenergy, and hydro) were considered. This is expressed in graphs describing the reduction of CO_2 emissions for 2010–2025 and increasing energy efficiency in different branches of the economy caused by the RES. Comparative analysis methods were also used to assess the efficiency of each type of RES and their contribution to the overall emissions reduction.

Table 1: CO_2 Emission Reductions by Type of Renewable Energy, 2010–2025 (in megatons, Mt)

Year	*Solar energy (Mt)*	*Wind energy (Mt)*	*Hydropower (Mt)*	*Bioenergy (Mt)*
2010	50	120	900	60
2015	150	350	950	120
2020	400	800	1000	200
2025	800	1200	1050	250

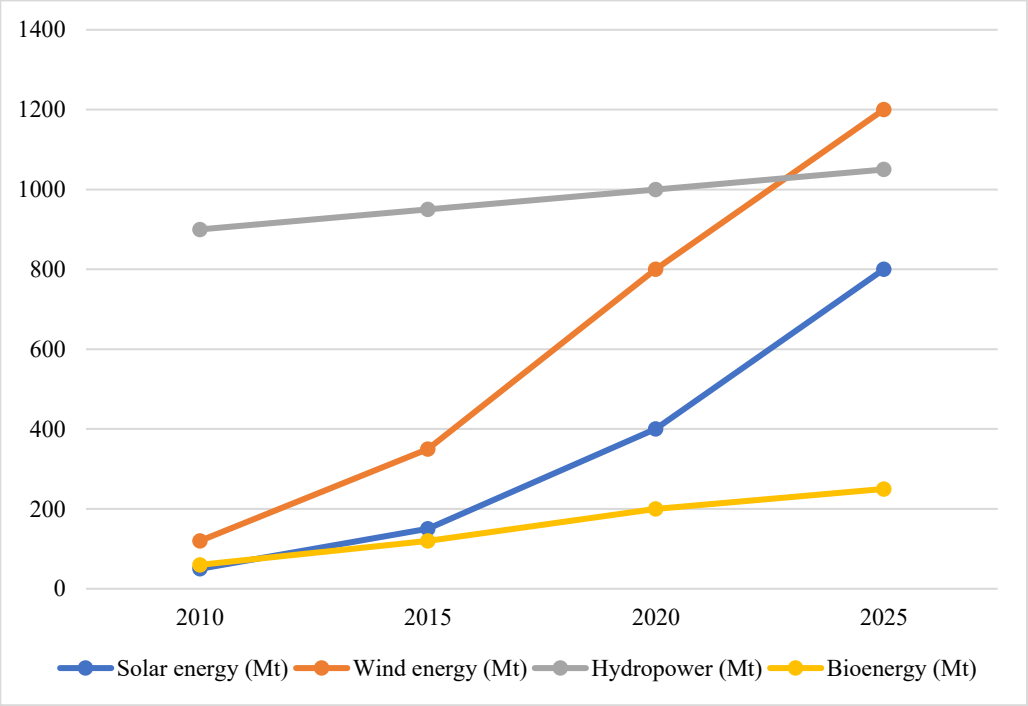

Figure 1: Reduction of CO_2 emissions due to RES (in megatons, Mt) [*Source:* Energy Agency (IEA) (2023), International Renewable Energy Agency (IRENA, 2023), World Bank (2023), U.S. Energy Information Administration (EIA, 2023), Eurostat (2023), National Energy Administration of China (NEA, 2023), State Agency on Energy Efficiency and Energy Saving of Ukraine (2023), Pata, Karlilar and Kartal, 2024]

The graph in Figure 1 shows the dynamics of CO_2 emission reductions from using different renewable energy sources (RES) from 2010-2025. The most significant contribution to emissions reduction is made by hydropower, which shows a relatively stable level of CO_2 emissions reduction, increasing by only 150 Mt throughout the period (from 900 Mt in 2010 to 1050 Mt in 2025). This indicates that most of the possible hydropower capacity has already been realised, and its further development has limited potential compared to other types of RES. Solar and wind energy are showing rapid growth in their efficiency in reducing emissions. Solar energy reduces CO_2 emissions from 50 Mt in 2010 to 800 Mt in 2025, a 16-fold increase in 15 years. Wind power has even more dynamic growth, increasing emission reductions from 120 Mt in 2010 to 1200 Mt in 2025, a 10-fold increase. The prominent increase for both sources will occur after 2015, coinciding with a global technological breakthrough in renewable energy and a reduction in the cost of the respective technologies. Bioenergy also shows positive dynamics, although its contribution is much smaller than that of other sources. CO_2 emission reductions increased from 60 Mt in 2010 to 250 Mt in 2025, corresponding to a 4-fold increase. This indicates that bioenergy is not seen as the primary tool for reducing emissions but plays a supporting role in decarbonizing the economy. Overall, the analysis shows that solar and wind energy demonstrate the fastest growth in CO_2 emissions reductions, indicating the effectiveness of support policies and investments in these sectors. From 2020 to 2025, the growth rate of emissions reductions will be the

highest, which may indicate the effectiveness of the implemented technologies and a further trend towards expanding RES capacity.

To improve data transparency and ensure compatibility with the journal's editorial standards, table 2 provides the values used for constructing the graph that illustrates the impact of renewable energy sources (RES) on energy efficiency improvements in different sectors from 2010 to 2025.

Table 2: Energy Efficiency Improvements Due to RES in 2010–2025 (% increase)

Year	*Overall energy efficiency improvement (%)*	*RES in industry (%)*	*RES in transport (%)*
2010	5	2	1
2012	7	3	2
2014	9	5	3
2016	12	8	5
2018	16	11	8
2020	20	15	12
2022	24	19	16
2024	28	23	19
2025	30	25	20

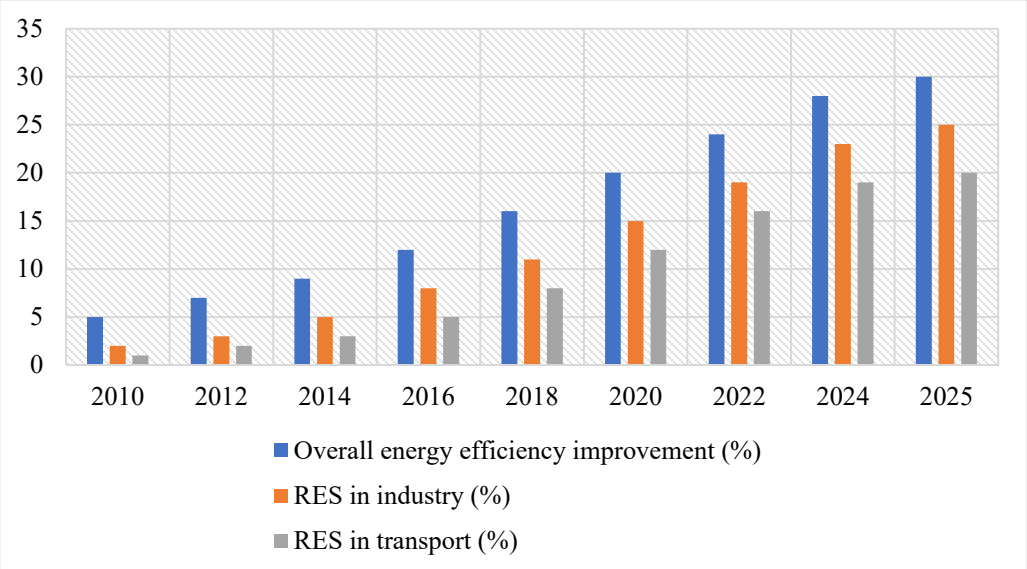

Figure 2: Increase in energy efficiency due to RES (%) [*Source:* Energy Agency (IEA) (2023), Eurostat (2023), International Renewable Energy Agency (IRENA, 2023), National Energy Administration of China (NEA, 2023), State Agency on Energy Efficiency and Energy Saving of Ukraine (2023), Pata, Karlilar and Kartal (2024), U.S. Energy Information Administration (EIA) (2023), World Bank (2023)]

The histogram in figure 2 shows the dynamics of energy efficiency improvement due to the introduction of renewable energy sources (RES) in the period 2010-2025 in three main areas: overall energy efficiency improvement, use of RES in industry, and the

transport sector. Overall energy efficiency is expected to grow steadily from 5% in 2010 to 30% in 2025, indicating a gradual introduction of energy-saving technologies and an increase in the share of clean energy in the overall energy balance. The fastest growth is in industry, where energy efficiency increased from 2% in 2010 to 25% in 2025. After 2015, there were main gains that can be explained by the active introduction of renewable energy sources to production processes, the development of energy-saving technologies, and the upgrading of environmental standards. The industrial sector is at 15% energy efficiency in 2020 and is foreseen to reach 25 % in 2025, according to global decarbonization trends and the production process's modernization. The transport sector is lagging in its development, although the overall progress remains positive. In 2010, 1% of the energy efficiency increase was due to renewables in transport; in 2025, this will be 20%. In 2015-2025, primary growth will occur due to the active introduction of electric transport, the development of biofuels, and the growth of energy-saving technologies in logistics. Overall, energy efficiency growth is driven mainly by industry, with renewables significantly impacting energy efficiency, particularly in the industrial sector. Continued advancements in efficiency will be achieved across all sectors of the economy, including water treatment, through technological innovation, enhanced support for clean technologies, and the establishment of new energy standards.

The development of green energy is the product of political strategy, whose parameters govern whether and how to supply, where and by what financing methods, with what technology, and what mechanism for regulating the energy market. Several governments are working proactively to develop the transition of energy resources (RES) through legislative initiatives, subsidies, and general agreements. These strategies focus on reducing dependence on fossil fuels and greenhouse gas emissions and guarantee sustainable development. However, the effectiveness of policies is also conditioned by the regional characteristics, the economic factors, and the level of international cooperation. Table 2 describes the relationship between political strategy and green energy development. Green energy development is dictated primarily by political strategies, i.e., priorities and financing mechanisms for environmentally friendly technologies. Countries with progressive energy policies demonstrate a rapid transition to renewable energy sources, which contributes to reducing CO_2 emissions and improving energy security.

Table 2: The relationship between political strategy and green energy development

Political strategy	*Impact on the development of green energy*	*Country example*
Legislative initiatives and environmental standards	Establishing standards for reducing CO_2 emissions and obligations to use renewable energy sources	EU (Green Deal)
Financial support and subsidies	Reducing the cost of implementing RES through government grants, preferential loans	USA (IRA Act 2022)
Carbon taxes and quotas	Economic incentives to reduce the use of fossil fuels	Canada, Sweden
International agreements and cooperation	Global regulation and climate change commitments	The Paris Agreement
Infrastructure	Construction of distributed energy	Germany

Political strategy	*Impact on the development of green energy*	*Country example*
development	networks and storage systems	(Energiewende)
Investments in science and technology	Developing new energy-saving technologies and improving the efficiency of renewable energy sources	China, Japan

At the same time, the effectiveness of policy measures depends on the availability of financial resources, public support, and international coordination. In the future, the further development of green energy will be determined by improved legislation, technological breakthroughs, and global climate change initiatives. The transition to renewable energy sources is important to the global energy transformation. However, the complete abandonment of traditional sources (coal, gas, oil) in the short term is challenging due to economic, technological, and infrastructure constraints. An optimal mix of renewable and conventional energy sources will ensure the stability of energy systems, provide affordable energy, and promote environmental sustainability (Table 3).

Table 3: Ways to achieve a balance between RES and traditional energy sources

Implementation Approach	*Expected effect*	*Example of implementation*
Development of energy storage technologies	Reducing the dependence of RES on weather conditions, increasing the stability of the supply	Tesla Powerwall, Germany (Energiewende project)
Optimisation of energy networks	Integrating RES into the grid, reducing energy losses	Smart Grid in the US and EU
Use of transitional energy sources	Temporary storage of gas and nuclear energy for stability	France (nuclear power)
Diversification of the energy balance	Combining renewables and conventional sources for an uninterrupted supply	Denmark (combination of renewables, gas, hydro)
Introduction of green hydrogen	Alternative storage of surplus RES for further use	Japan (H_2 energy)
Financial support and tax incentives	Stimulating the development of renewable energy sources and modernising conventional energy	USA (Inflation Reduction Act 2022)
Development of regional strategies	Flexible mix of energy sources depending on the needs of the region	China (diversity of energy mix in provinces)

Ensuring an optimal balance between renewables and conventional energy sources requires a comprehensive approach that includes technological development, infrastructure modernisation, and financial support. The use of hybrid systems, the development of storage technologies, and the integration of green hydrogen will gradually reduce dependence on fossil fuels while ensuring the stability of the energy

supply. A successful transition is possible with active government policy, research investment, and strategies for adaptation to regional energy market characteristics.

Discussion

Environmental Benefits

According to these findings, the use of renewable energy sources (REs) is important to achieve SDG 7. The analytics of the data proved that a rising portion of RES in the total energy mix has a quantifiable impact of impacting the environment. In particular, solar and wind energy were revealed to respond effectively to the low emission of CO_2, which is consistent with previous research studies (Pata, Karlilar and Kartal, 2024; Xia, Liu and Yang, 2023). Hydro power levels off in contribution, and bio energy has a supplementary role. Such trends confirm that the use of RES is one of the methods of decarbonisation and the promotion of favourable air and human health.

Economic and Financial Codes

Although there are benefits in relation to the environment, the implementation of RES still suffers from huge financial challenges, particularly in developing nations. Although world technology costs have dropped, this does not help since the cost of procurement remains high up front, especially where international financing is not readily available. These facts align with Duggan (2025) and Wu *et al.* (2024), who state that financial instruments play a vital role in the implementation of RES. The low infrastructure, the accessibility of the grid, and the lack of capital further hamper the move towards the energy change.

Policy and Governance

We add to the conclusion of Zhang *et al*. (2023) that coherent and proactive political strategies remain essential when carrying out effective implementation of RES. The countries with favourable legislation, environmental standards, and long-term plans, e.g., the Green Deal in the EU and the IRA Act in the USA, show more rapid deployment rates. Areas under regulatory uncertainty or where there is divided governance make less progress in comparison. The analysis showed that aligning national and international policies, such as those with the Paris Agreement, enhances implementation capacity and boosts stakeholder confidence.

Technological Potential

The key importance of the combination of digital technologies and smart infrastructure is in helping to realise the full potential of RES. Intelligent switching, smart grids, and transformers (e.g., SFTSZ) play a key part in increasing the stability, efficiency, and flexibility of a network to variable generation. Real-time energy measurement and dynamic load sharing are particularly applicable to decentralised systems and microgrids. Nonetheless, most of the current deployments are on high-voltage grids, and low-voltage and rural areas are underdeveloped. The need to have national standards on

synchronization and smart-switching in implementation in order to have resilient urban and remote settings is urgent.

Regional Disparities and Integration Aspects

Another key finding of the research is that the adoption of RES is not evenly distributed across the regions. Whereas advanced economies experience a surge in the capacity provided by renewable sources, the developing countries still have to deal with a twofold pathway: on the one hand, providing universal energy access; on the other, phasing out fossil fuels. This inequality is only made worse by varying degrees of technological preparedness, investment potential, and institutional capability. Mini-grids and autonomous generation, which are examples of decentralised solutions, become relevant especially in areas with scattered populations or where the infrastructure is weak following a conflict.

Conclusion

Ensuring an affordable, environmentally friendly, and cost-effective energy supply is one of the important factors in the Sustainable Development Goal (SDG7), which includes renewable energy sources (RES). The study shows that introducing renewable energy sources significantly reduces CO_2 emissions and improves energy efficiency. However, their deployment has an uneven pace for regional economic and political reasons. The main novelty of the results is identifying the critical role of political strategies and financial mechanisms in accelerating the energy transition, which allows us to identify priority areas for future reforms. The study's practical significance lies in the formulation of recommendations for strengthening support for decentralised energy solutions and developing infrastructure for integrating RES into national energy systems. A limitation of the work is the dependence on available statistical data and the lack of long-term forecasts on the impact of new technologies such as green hydrogen. Promising areas for further research include analysing the effectiveness of various policy incentives, exploring the potential of renewable energy in developing countries, and assessing the impact of digitalisation on energy transformation. Sustainable development requires an in-depth study of the relationship between technological innovations, market mechanisms, and environmental goals, which will allow for the development of comprehensive strategies for the transition to a low-carbon economy.

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*
Conceived and designed the research or analysis	Yes	No	Yes	Yes	No
Collected the data	No	No	Yes	Yes	Yes
Contributed to data analysis and interpretation	Yes	Yes	No	No	No
Wrote the article/paper	Yes	Yes	No	No	No
Critical revision of the article/paper	No	Yes	No	Yes	No
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